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ITATION PAGE

Form Approved
OMB No. 0704-0188

AD-A222 277

ORT DATE	3. REPORT TYPE AND DATES COVERED
17 Apr 1990	Final Report/1 Dec 88-30 Nov 89

4. TITLE AND SUBTITLE
Research with Scanning Tip Microscopes

5. FUNDING NUMBERS
61104D/3842/A6

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AFOSR-TR-

8. PERFORMING ORGANIZATION REPORT NUMBER
90-0577

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AFOSR/NP
Bolling AFB DC 20332-6448

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
AFOSR-89-0204

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

An atomic force microscope has been developed using a laser diode as the interferometer which senses the minute deflection of the force sensing tip. The system, which has been incorporated inside a commercial instrument (Digital Instruments) is capable of detecting atomic steps on graphite. The instrument is also being used to profile magnetic and electric fields on storage media and IC chips, respectively.

Integrated Circuit

14. SUBJECT TERMS
atomic force microscope, magnetic and electric fields, optics, STM, ultrahigh Vacuum System, Scanning (SG)

15. NUMBER OF PAGES
5

16. PRICE CODE
UL

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

90 05 [illegible] 130

Final Technical Report

Research with Scanning Tip Microscopes

Submitted to

Air Force Office of Scientific Research

(grant no. AFOSR-89-0204)

April 17, 1990

Research Accomplishments

(1) Force Microscopy

We have developed an atomic force microscope using a laser diode as the interferometer which senses the minute deflection of the force sensing tip. The system, which has been incorporated inside a commercial instrument (Digital Instruments) is capable of detecting atomic steps on graphite. Figure 1 shows a blood cell taken with such a head (courtesy Digital Instruments). We are also using this instrument to profile magnetic and electric fields on storage media and IC chips, respectively.

(2) Scanning Tunneling Microscopy

(a) UHV Studies

A great deal of effort has been involved in setting up an ultrahigh vacuum system for imaging semiconductor clusters. The main vacuum chamber has Auger, LEED, and STM capabilities. Samples are prepared by evaporation in a preparation chamber. They are then transferred to the main chamber for surface characterization with regard to surface composition and order before scanning tunneling imaging or spectroscopy is done.

Some results have been obtained for samples prepared under UHV conditions but imaging was done in air. Imaging in air is possible if the deposited overlayer material is inert. A metal complex (molydenum tetracetate) deposited on graphite is an example. This study serves as a test case of the operation capability of our STM.

Figure 2 shows an STM image of an overlayer of molydenum tetracetate on molybdenum disulphide. Computer modeling of the arrangement of the molecules on the surface shows that these molecules show different packing arrangement depending on the concentration of these molecules on the surface. At low concentration (< 0.5 ML), the pan-cake shaped molecules packed with the flat faces move on less parallel to the substrate forming a shingle-like structure. At higher concentrations, the molecules come together like a stack of coins lying with their edges on the surface. The study demonstrates the possibility of using STM to study the growth of semiconductor clusters under UHV conditions.

(b) Biological Specimens

Using the STM in air, we obtained images with atomic resolution of the protein cytokeratin. Each cytokeratin filament is made up of 4 separate alpha helical strands (tetramers) which intertwine in pairs called dimers. Four levels of organization of the protein structure can be distinguished. The primary level or organization are the arrangements of the amino acids in the protein structure. Amino acids with ringed

structure (e.g. phenyl alamine and histidine) can be identified (see Fig. 3 a). The secondary structure is the helical arrangement of each strand. This is evident in Fig. 3a. The tertiary structure results in the formation of dimers and tetramers as seen in Fig. 3b. The stacking arrangement of the tetrameters to form quantenary structure can also be seen.

Fig. 1. Red blood cell ($20\mu \times 20\mu$).

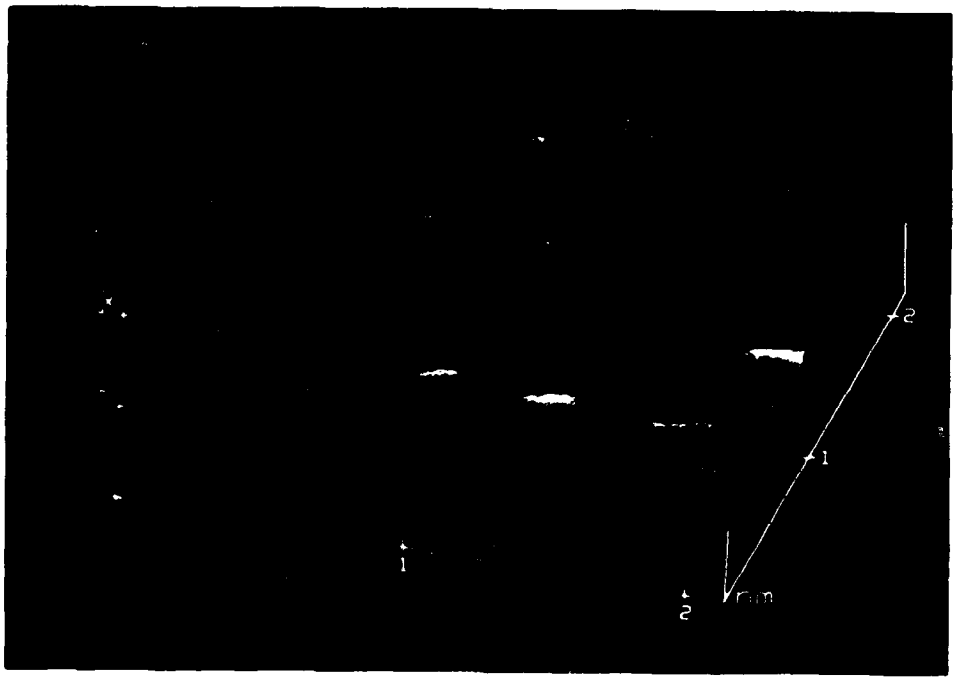

Fig. 2. A layer of Molybdenum Tetracetate on MoS_2.

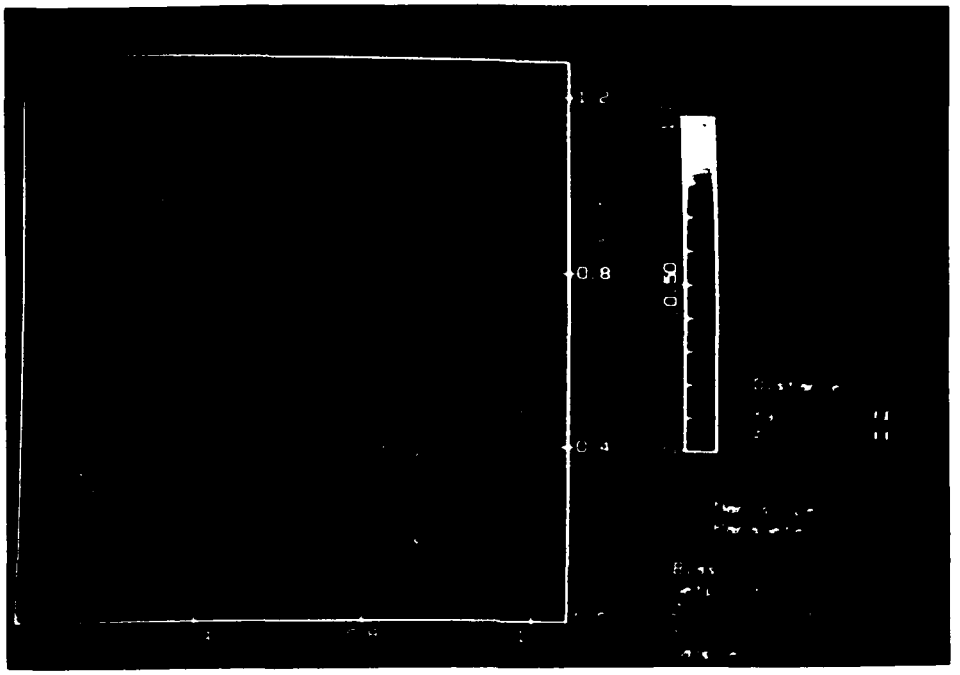

Fig. 3a. An aminoacid (histidine) observed on cytokeratin.

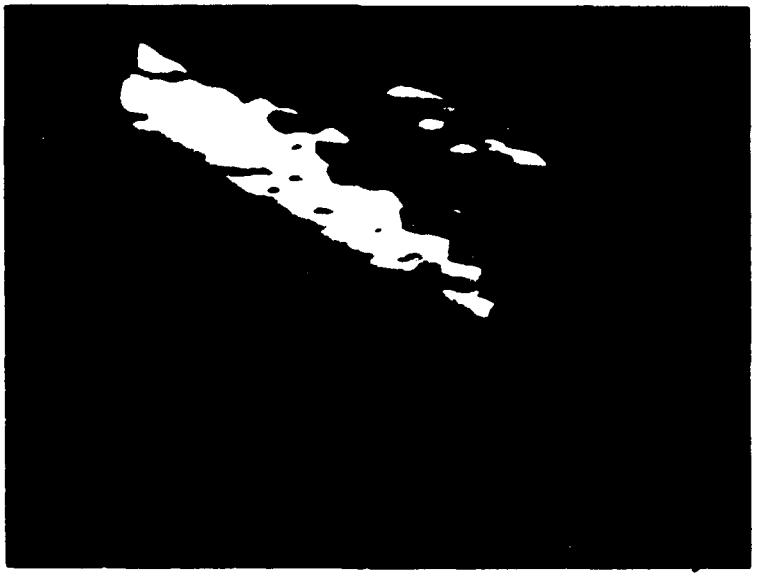

Fig. 3b. A cytokeratin dimer.